STEM Education in Japanese Technical High School : Through Curriculum Development of the Robot Education

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Abstract

Most Japanese schools emphasize mathematics and science as regular subjects. However, a few high schools emphasize technology and engineering. In an elementary and junior high schools, the subject to learn technology is in only a technical course of the junior high school. Students in the general course of high schools don't study technology and engineering. Therefore, we do not hear the word "STEM education" very often in Japan. Super Science High Schools（SSHs）are a designation awarded by the Japanese Ministry of Education, Culture, Sports, Science and Technology（MEXT）to upper secondary schools that prioritize science, technology, and mathematics. Some Super Science High Schools are trying educational practices just like STEM education in other countries.

The author was engaged in technology education in Tokyo Tech high school of science and technology which was one of the Super Science High Schools in Japan, and have been involved in robot education as a teacher of the machine course. In this paper, we propose a curriculum development of the robot education including the evaluation of the curriculum and description sample projects such as underwater robots and the 3D food printing system for Japanese sweets.

Key Words: Curriculum Development, Robot Education, Japanese Technical High School, STEM Education

1. A Brief Review of Japanese Educational System

The Japanese educational system was reformed after World War II. The old 6-5-3-3 system was changed to a 6-3-3-4 system (6 years of elementary school, 3 years of junior high school, 3 years of senior high school and 4 years of University) with reference to the American system. The compulsory education period is 9 years, 6 in elementary school and 3 in junior high school. School year starts in April and ends in March. Japanese schools incorporate a national curriculum created by the MEXT .

After graduating from junior high school, students choose to continue their education to high school and then to university or to find employment.

Ninety seven percent of junior high school students go up to senior high schools and approximately fifty four percent of senior high school students go up to college or university. Many graduates of the department of science and engineering enter a masters course. Most of elementary schools and junior high schools are public, for they are compulsory education. Senior high schools, colleges, universities are both public and private. Japanese educational system is shown in Fig.1.

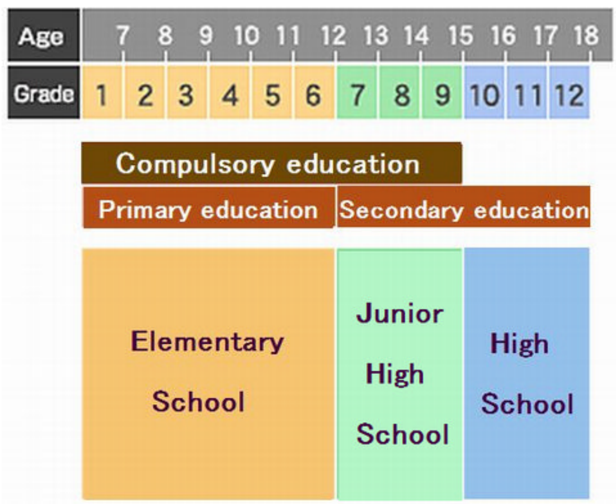

Fig.1 Japanese Educational System

2. Technology Education as General Education

Within Japan there are calls for the promotion of innovation towards making Japan a technology leading country. Scientific and technical education in our schools is meeting the challenge. Scientific and technical education is not only science and mathematics - it is necessary to spend time for education in '*monozukuri*', simply means making things with a deeper impression of skilled craftsmen pouring heart and soul into their work in Japanese.

As for one of the subjects, called 'Art and Handicraft' in elementary schools, children have two classes a week as a regular subject. The aim of this subject is to involve children in activities expression and appreciation, to savor the joy of creating while bringing their sensitivity into play. This is art education rather than technology education.

As for one of the subjects, called 'Technology and Home Economics' in junior high schools is the only formal compulsory subject for technology in Japan. However, junior high school students have only two classes a week.

Objectives: To enable students to acquire basic knowledge and skills related to materials processing, energy conversion, growing plants and information processing through practical activities such as making things（*monozukuri*）. Furthermore, to make students understand the relationship between the technology and the environments, and develop the ability and attitude to evaluate and make use of technology properly.

Contents: A. Technology of materials and processing, B. Technology of energy conversion, C. Technology of growing plants, D.Technology of information processing.

In particular, D.Technology of information processing includes design works and computer programs. Therefore, we introduce Fab Lab activities here. However, the digital machine tools such as a laser cutter or a 3D printer have not been available in Japanese elementary schools nor junior high schools.

Over 97 percent of junior high school students go up to senior high schools. There are three categories: (1) general course, (2) specialized course (former vocational), and (3) integrated course.

(1) General course provides mainly general education for the students who wish to advance to higher education and those who wish to get a job after graduation.They have no specific vocational subjects.

(2) Specialized courses provide mainly vocational or other specialized education for those who have chosen a particular vocational fields as their future career. These courses classified into the followings : industry, commerce, fishery, agriculture, science-mathematics, home economics, nursing, physical education, music, art, English language and other courses.

(3) Integrated courses were introduced in 1994. These courses offer a wide variety of subjects in both the general courses and the specialized courses, in order to satisfy students' diverse interests for future career plans, and develop their abilities and aptitudes, etc.

The percentage of general course is 72.6, that of industrial course is 7.8, commercial course is 6.2, agricultural course is 2.5 and others in 2014. In general course, most of the students have never studied technology and the other vocational subjects and go up to university. Even if the students who proceed to study engineering at universities have never studied technological and vocational subjects at senior high school level unlike in other countries.

3. STEM Education in High Schools

3.1 Super Science High Schools

In the United States, STEM education depends on its readership among nations, its own solution for immense challenges in energy, health, environmental protection, and national securiry.

Super Science High Schools（SSHs） is a designation awarded by the Japanese Ministry of Education, Culture, Sports, Science and Technology（MEXT） to upper secondary schools that prioritize science, technology, and mathematics[1]. The program was launched as part of its "Science Literacy Enhancement Initiatives" in 2002. Schools with this status receive increased funds and are encouraged to develop links with universities and other academic institutions. Approximately 30 high schools are appointed as SSHs every year, and the budget is increasing every year.

Students of SSHs are expected to be advanced high leveled scientists and engineers. Besides theories of those subjects as mathematics, physics, chemistry, biology, etc. those students in SSHs are involved in project studies. Many local meetings where students make a presentation for their research results study take place in each region every year, and the national meeting is held every summer. There come family members, high school teachers, and university professors to observe theire presentation.

Many Super Science High Schools emphasize the education of mathematics and science. However, a few high schools emphasize technology and engineering. It results from the lack of facilities of making things by using 3D printers and laser cutters. That is why the STEM Education is not popular in Japan yet.

3.2 Tokyo Tech High School of Science and Technology

Tokyo Tech High School of Science and Technology is the only national high school of science and technology in Japan, which has a long history over a century and offers an educational basis in science and technology. It has five fields of specialization: applied chemistry, information systems, machine design, electrical and electronics, and architectural design. There are about 600 students in this high school, and most of thems enter colleges and other higher institutes of science and technology［2］.

This high school had been designated as a Super Science High School in 2002 its been 13 years since then. This school used to is be a technical high school. Therefore it provides not only the education of science and mathematics but also the education of engineering and technology. The characteristic of its curriculum is to encourage the students acquire bases of science and technology both theoretically and practically, and make them capable of pursuing education of science and technology at college and still higher institutes. That is, the very example of the STEM education in Japan.

The author used to be a teacher in machine design course from 1993 to 2014. We have developed the curriculum of robot education［3］. Further detail is described in next section.

4. Curriculum Development of Robot Education

4.1 Curriculum of Machine Design Course

Educational objectives of machine design course are to develop students' basic ability of mechanical engineering and robotics and help them acquire a fundamental knowledge from which they can advance to a higher education level. We have developed new lessons such as robot contest and control of the single-board micro computer. The digital fabrication machines such as a 3D printer and a laser cutter were recently introduced into the course. Third-year students work on the project study. The characteristic of our curriculum is to enable the students to learn the theories and experiences practical activities connected to the future advanced researches ［4］.

First-year（10th-grade） students don't belong to the specialized course. In addition to mathematics, physics, and chemistry, they study basic experiments about science and technology. They also study 'basic mathematical science in industry', and 'basic programming by using C language'.

They belong to specialized course from second-year（11th-grade）. Second-year students who belong to machine design course study above subjects about mechanical engineering and robotics. Third-year（12th-grade）students study much more specialized subjects, and work on the project study. Curriculum of machine design course is shown in Table.1.

Table.1 Curriculum of Machine Design Course

・**11th-grade**（unit）
Practice（3）
lathe turning, drilling, milling, NC machine, welding, casting, single-board microcomputer（Arduino）,
Drawing（2） drafter, 3DCAD（SolidWorks）
Digital Fabrication（2）
3D printer , laser cutter, vinyl cutter,
Robotics（2）
mechanism using LEGO
robot contest, pneumatic control using PLC
Leading-edge of technology（1）
lecture by the university teacher
・**12th-grade**（unit）
Machine design（2）
Machine craft（2）
Project study（4）

4.2 Project Study

'Project study' is the subject : 3-5 students work on research in a group. Machine design course students have developed underwater robots and two-legged robots, automatic cooking robots, automatic performance robots, 3D food printing system for Japanese sweets, etc. The followings are some of the examples.

（1） Underwater Robots

We have been developing the underwater robot since we developed a fish robot in 2002, and recently developed biomimetic robots such as a dolphin robot, a penguin robot and a sea turtle robot. Body of the underwater robots is made of engineering plastics. Laser cutter has recently been used for plastics processing. Adjustment of the buoyancy is difficult. To keep underwater robots waterproof completely is hard. We participate in the underwater robot convention every year and we won different prizes several times.

Fig.2 Sea Turtle Robot

(2) 3D Food Printing System for Japanese Sweets

Three 3D printers of fused deposition modeling (FDM) type were introduced into our school in recent years. Gradually, we wanted to make a 3D printer by ourselves. First, We made a RepRap (Replicating Rapid-prototyper) typed 3D printer. Everything about RepRap is open-source and we can make it ourselves. Next, we improved this 3D printer into a food printer for Japanese sweets using white bean paste. 3D printer was used for making an extruder. This food printer has attracted many people's attention at Make Faire Tokyo in 2014.

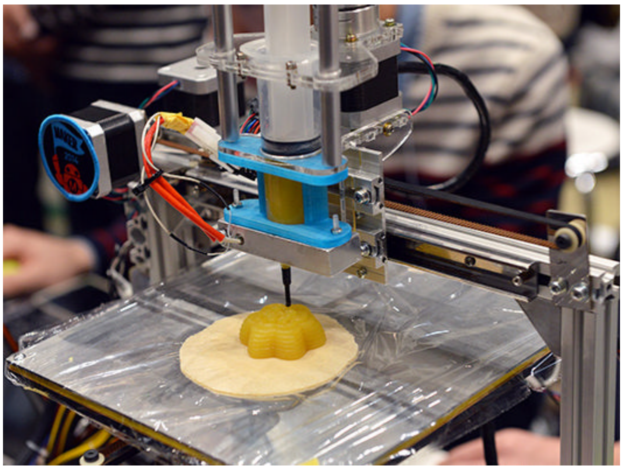

Fig.3 3D Food Printing System for Japanese Sweets

4.3 Evaluation of the Curriculum

We evaluate the curriculum of the robot education according to four viewpoints.

They are 1. interest and attitude 2. idea and judgement 3. skills and expression 4. knowledge and understanding.

Evaluation methods include an examination (essay, oral test, objective test, etc.), a questionnaire about lesson, curriculum, evaluation, etc., an interview of individual, and group.

Evaluation has two viewpoints, standard and criterion. Standard means numerical target achievement. For example, over 80 is A level, over 60 is B level, over 40 is C level, on a scale of 0 to 100. Criterion means what the students can do and can understand.Considering all the various factors, we teachers examine the curriculum carefully.

5. Conclusion

'Technology and Home Economics' in junior high schools is the only formal compulsory subject for technology in Japan. In general course of high school, most of the students have never studied technology and the other vocational subjects.

Tokyo Tech high school provides not only the education of science and mathematics but also the education of engineering and technology both theoretically and practically. That is, the very example of the STEM education in Japan.

We propose a curriculum development of the robot education including the sample projects and the evaluation of the curriculum.

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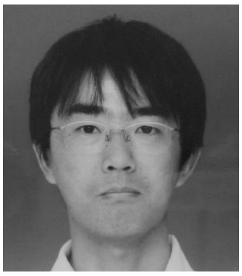
Profile Kazuo KADOTA



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